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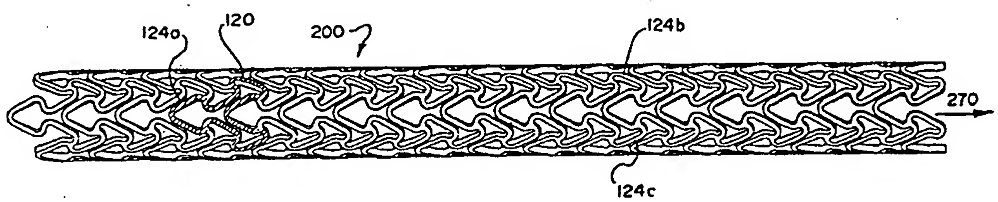


(57) Abstract

A generally cylindrical, radially expandable stent may be composed of a plurality of interconnected multibonate cell structures. The cells have three or more enlarged end portions radiating from a common center within the cell. The cells may be of tribonate or higher order multibonate configuration. Stents composed up of a series of generally multibonate cell elements are also disclosed.

IMPROVED STENT CELL CONFIGURATIONS

Background of the Invention

This application is a continuation-in-part of US Application No. 09/036665 filed March 4, 1998, the contents of which is incorporated herein in its entirety by reference.

Field of the Invention

This invention relates to stents of improved cell configuration.

Brief Description of the Prior Art

Stents are radially expandable endoprostheses which are typically intravascular implants capable of being implanted transluminally and enlarged radially after being introduced percutaneously. They have also been implanted in urinary tracts and bile ducts. They are used to reinforce body vessels and to prevent restenosis following angioplasty in the vascular system. They may be self-expanding or expanded by an internal radial force, such as when mounted on a balloon.

In the past, stents have been generally tubular but have been composed of many cell configurations and have been made of many materials, including metals and plastic. Ordinary metals such as stainless steel have been used as have shape memory metals such as Nitinol and the like. Stents have also been made of biodegradable plastic materials. Such stents have been formed from wire, tube stock, and the like.

Summary of the Invention

This invention provides new configurations of the cells making up stents which may be adapted to all of the various types of prior art stents described above and/or known previously in the art. In general, as will be seen from the embodiments described hereinafter, the improved cell configurations are generally trichotomous, i.e., divided into three parts. More particularly, the cells are of a triskelion-like or trifurcate configuration, i.e., composed of three parts with axes of each part radiating from a common center. There are numerous advantages to the new configurations. For example, the configurations of the invention limit recoil and add resistance to

Figure 11 is a flat plan view showing yet another embodiment of the invention;

Figure 12 is a flat plan view showing a bonate cell structure;

Figure 13 is a flat plan view showing a multibonate (tribonate) cell structure;

Figure 14a is a flat plan view showing yet another tribonate embodiment of the invention;

Figure 14b is a flat plan view showing the rotational axis of symmetry of the multibonate cells of Fig. 14a;

Figure 14c is a flat plan view showing the planes of reflectional symmetry of the multibonate cells of Fig. 14a;

Figure 15a is a flat plan view showing yet another tribonate embodiment of the invention;

Figure 15b is a flat plan view showing the plane of reflectional symmetry of the multibonate cells of Fig. 15b;

Figure 16a is a flat plan view showing yet another tribonate embodiment of the invention;

Figure 16b is a side elevational view of the stent of Fig. 16a;

Figure 16c is a three dimensional isometric view of the stent of Fig. 16a;

Figure 16d is a magnified view of an end portion of the stent as shown in Fig. 16d;

Figure 16e is a three dimensional isometric view of a stent similar to that of Fig. 16c, but shorter;

Figure 17 is a flat plan view showing yet another embodiment of the invention which includes tribonate and bonate structures;

Figure 18 is a flat plan view showing yet another embodiment of the invention which includes tribonate and bonate structures;

Figure 19 is a flat plan view showing a quadribonate embodiment of the invention;

Figure 20a is a flat plan view showing yet another quadribonate embodiment of the invention;

Figure 20b is an enlarged portion of Fig. 20a showing the various planes of symmetry;

Finally, the longitudinal axis of the stent is indicated by reference numeral 270 in the above figures and in all of the remaining figures of the application.

When the stent of Figures 1 and 2 is expanded, as shown in Figure 4, on a balloon for example (not shown), the cells 11 take on a new configuration as shown, the segments making up the stent being indicated by the same numbers as used in Figures 1 and 3.

Referring now to Figures 5-6, another internested stent embodiment is shown. In this embodiment, as seen in Figures 5 and 6, expansion cells 11, best seen in the detail of Figure 6 (again a cell is indicated by darkening) are shaped the same as cells 11 in Figures 1-3. However, they are skewed with respect to the longitudinal axis 270 of the stent rather than being arranged in parallel longitudinal lines in which the cells are positioned perpendicular to the longitudinal axis of the stent as in Figures 1-4.

Referring now to Figure 7, another cell configuration is shown to demonstrate that elements or segments 12, 14 and 16 need not be straight but may be arcuate as shown, either inwardly as shown in the Figure or outwardly.

The cell configuration shown in Figure 8 is a three-lobed configuration preferably used in an interconnected cellular arrangement with individual connecting members as discussed in Figures 9 and 10. In this embodiment three sections, 12a/12bm 14a/14bm and 16a/16b, radiate from a common center to terminate in enlarged end portions 13, 15 and 17, respectively. However, Figures 9 and 10 make use of cell configurations similar to those shown in Figures 1-6.

In Figure 9, a series of sets of cells, each set consisting of six cells 11 arranged in a circular pattern 28, repeated throughout the stent body. Each cell 11 is connected to three adjacent cells 11 by three connector segments 30 in a repeating pattern through the stent body. In this particular arrangement, the connector members 30 extend from an inner segment on one cell to an inner segment on an adjacent cell, as shown. The connector members may be straight or curved and may be in various shapes such as zig-zag or S-shaped, etc.

In Figure 10 the connector members 30 extend from an inner segment on one cell to an outer segment on the adjacent cell as shown. Cells 11 are arranged in vertical rows in this embodiment but are staggered longitudinally as can be seen in the Figures.

cell structures may optionally be regularly arranged. One such stent is shown in the flat in Fig. 14a. Stent 200 consists of a plurality of interconnected tribonate cell structures 120. Tribonate cell structures are arranged in interconnected longitudinal rows 204. Tribonate cell structures within a row are seen to be tessellated or interlocking with adjacent cell structures having at least one member 124a in common. Member 124 simultaneously serves as an end portion of a cell structure and as a portion of the central portion of a cell structure. Tribonate cell structures 120 in adjacent rows 204 are also seen to share a member 124b in common. Member 124b, similarly, serves as an end portion in one cell structure and as a portion of the central portion of a cell in an adjacent row. All of the tribonate structures 120 in adjacent rows 204 of multibonate structures are identically oriented relative to the longitudinal axis of the stent.

It is further noted that tribonate cells 120 of Fig. 14a have a common portion 128 which is substantially triangular and moreover formed substantially in an equilateral triangle. Each tribonate cell 120 has a threefold rotational axis of symmetry (C_3 axis of symmetry) 121 in the flat, through the center of the cell, as shown in Fig. 14b. Each tribonate structure further is characterized by three planes of reflectional symmetry (σ_v) 123a-c, as shown in Fig. 14c. To that end, first, second and third end portions 124a-c, respectively, are the same shape. Moreover, all three connecting portions 132a-c are substantially the same shape, width and length.

The invention further contemplates variations on the multibonate structure in general and the tribonate structure in particular. One such variation is shown in stent 200 in Fig. 15a. Tribonate cell structure 120 is not seen to possess the threefold rotational symmetry of the tribonate cell structure of Fig. 14a. Moreover, cells 120 are seen to possess only a single plane of reflectional symmetry (σ_v) 123, as shown in Fig. 15b. The cell structure is also seen to vary in that second and third end portions 124b,c are a reflection of one another while end portion 124a differs in shape. End portion 124a is substantially triangular in shape. Its boundaries are defined by two convex side portions 136a,b. End portions 124b,c are each seen to be mushroom shaped. Each of end portions 124a-c extend from connecting portions 132a-c, respectively, which in turn, extend from common portion 128. End portions 124a-c are seen to be mushroom shaped.

Another embodiment of the invention is shown generally at 200 in Figs. 16a-e. As in Fig. 15, tribonate cell structure 120 does not possess the threefold

The invention also contemplates stents in which multibonate cells include an end portion which is parallel to the longitudinal axis of the stent. Such a stent is shown generally at 10 in Fig. 1. End portions 124b are aligned parallel to the longitudinal axis 270 of the stent.

Yet another embodiment of the invention is shown generally at 200 in Fig. 19. Stent 200 is comprised of a series of interconnected, internested quadribonate cells 120 including first quadribonate cells 120a and second quadribonate cells 120b. First and second quadribonate cell 120a,b are differently shaped. End portions 124a of first quadribonate cells 120a also serve as side portions of adjacent second quadribonate cells 120b. First quadribonate cells 120a are joined together by connecting members 154 which also serve as end portions 124b for quadribonate cells 120b. End portions 124a of first quadribonate cell structures 120a are oriented at oblique angles relative to longitudinal axis 270. End portions 124b of second quadribonate cell structures 120b are oriented parallel or perpendicular to longitudinal axis 270 of stent 200. The stent of Fig. 19 is an example of a multibonate stent which consists of at least two different types of multibonate cells of the same order.

Another quadribonate stent is shown generally at 200 in Fig. 20a. Stent 200 is formed of a series of interconnected, internested quadribonate cells 120 including first quadribonate 120a and second quadribonate cells 120b. End portions 124a of first quadribonate cell structures 120a are oriented at oblique angles relative to longitudinal axis 270. End portions 124b of second quadribonate cell structures 120b are oriented parallel or perpendicular to longitudinal axis 270 of stent 200. Stent 200 further includes bonate cell structures 140 oriented at oblique angles relative to the longitudinal axis 270 of the stent. The stent of Fig. 20a is an example of a multibonate stent which consists of at least two different types of multibonate cells of the same order and further contains bonate cells.

The quadribonate cells of Figs. 19 and 20 have a four-fold axis of rotational symmetry. Fig. 20b shows this axis 121 for one quadribonate cell 120b of Fig. 20a. The quadribonate cells also are characterized by four planes of reflectional symmetry 123a-d.

The invention is also directed to a stent, shown generally at 200 in Fig. 21a, which includes elongated tribonate cell structures 120 as well as a row of bonate cell structures 140 at one end of the stent. Tribonate cells 120 include a relatively long,

from a common portion 166. The invention contemplates stents in which adjacent multibonate structures have at least one side in common, as shown in Fig. 9, as well as stent in which adjacent multibonate structures do not have at least one side in common.

The invention is also directed to stents comprising at least one multibonate structure of n^{th} order and at least one bonate structure or multibonate structure of m^{th} order where n and m are integers, n and m are greater than 2 and $n \neq m$. These stents comprise at least one multibonate structure of a desired order and one bonate structure or multibonate structure of a different order.

The stent of Fig. 9 comprises sixth order multibonate structures (hexabonate) 150 as well as third order (tribonate) structures 120. The different order multibonate structures may be interlocking, having parts in common. Tribonate structures 120 in Fig. 9 are interconnected by connecting segments 154 which also serve as end portions of hexabonate cell structures 150. The different order multibonate structures may also be separate from one another and interconnected via connecting members.

The invention also contemplates stents formed of at least two different types of multibonate cell structures of the same order. For example, the two different types of multibonate cells may have different dimensions or different shapes. This is illustrated in Fig. 10. The stent, shown in the flat, includes first tribonate cells 120a and second tribonate cells 120b. The shape of first tribonate cells 120a differs from that of second tribonate cells 120b. Figure 19 similarly includes two different types of quadribonate cells 120a,b.

The invention is also directed to a stent comprised of at least one cell structure selected from the group consisting of bonate cell structures oriented at an oblique angle relative to the longitudinal axis of the stent, multibonate cell structures and combinations thereof. Desirably, the stent will be composed comprised of a plurality of cell structures selected from the group consisting of bonate cell structures oriented at an oblique angle relative to the longitudinal axis of the stent, multibonate cell structures and combinations thereof. Optionally, the cell structures will be interlocking.

The invention is further directed to a stent comprising one or more bonate structures oriented at an oblique angle relative to the longitudinal axis of the stent. As shown in the flat in Fig. 23, stent 200 consists of interconnected bonate cell structures 140. The stent includes first bonate cell structures 140a which are oriented at

What is claimed is as follows:

1. A stent of generally cylindrical shape comprised of at least one multibonate cell structure.

2. The stent of claim 1 comprised of a plurality of interconnected multibonate cell structures.

3. The stent of claim 2 wherein the multibonate cell structures are regularly arranged.

4. The stent of claim 2 wherein all of the multibonate cell structures are tribonate, each tribonate structure having

a common portion;

a first connecting portion extending from the common portion;

a first end portion extending from the first connecting portion;

a second connecting portion extending from the common portion;

a second end portion extending from the second connecting portion;

a third connecting portion extending from the common portion; and

a third end portion extending from the third connecting portion.

5. The stent of claim 4 wherein the multibonate structures are arranged in interconnected longitudinal rows.

6. The stent of claim 5 wherein at least some of the multibonate cell structures are tribonate.

7. The stent of claim 6 wherein adjacent rows of multibonate structures have connecting members extending therebetween.

8. The stent of claim 6 wherein adjacent multibonate structures within a row are interlocking.

9. The stent of claim 6 wherein adjacent rows of multibonate structures have connecting members extending therebetween, the connecting members being bonate cell structures.

10. The stent of claim 9 wherein each bonate cell structure is disposed at an oblique angle relative to the longitudinal axis.

11. The stent of claim 10 wherein the bonate cell structures are arranged in longitudinal rows,

all of the bonate cells within a row disposed at the same oblique angle,

a second side portion opposite the first side portion and extending from the connecting portion; and

an end base portion extending between the first and second side portions, wherein the base portion is substantially linear.

25. The stent of claim 23 wherein the substantially rectangular end portions are formed of

a first side portion extending from the connecting portion;

a second side portion opposite the first side portion and extending from the connecting portion; and

an end base portion extending between the first and second side portions, wherein the base portion is a convex curve.

26. The stent of claim 6 wherein at least some of the multibonate structures are hexabonate structures.

27. The stent of claim 26 wherein adjacent hexabonate structures have at least one side in common.

28. The stent of claim 26 further comprising tribonate structures.

29. The stent of claim 28 wherein the hexabonate and tribonate structures are interlocking.

30. The stent of claim 8 comprising at least one multibonate structure of n^{th} order and at least one multibonate structure of m^{th} order

where n and m are integers greater than 2; and

$n \neq m$.

31. The stent of claim 6 wherein all of the multibonate cell structures are of the same tribonate cell structure.

32. The stent of claim 6 comprising interconnected quadribonate cell structures.

33. A stent comprised of at least one cell structure selected from the group consisting of bonate cell structures oriented at an oblique angle relative to the longitudinal axis of the stent, multibonate cell structures and combinations thereof.

34. The stent of claim 33 comprised of a plurality of cell structures selected from the group consisting of bonate cell structures oriented at an oblique angle relative to the longitudinal axis of the stent, multibonate cell structures and combinations thereof.

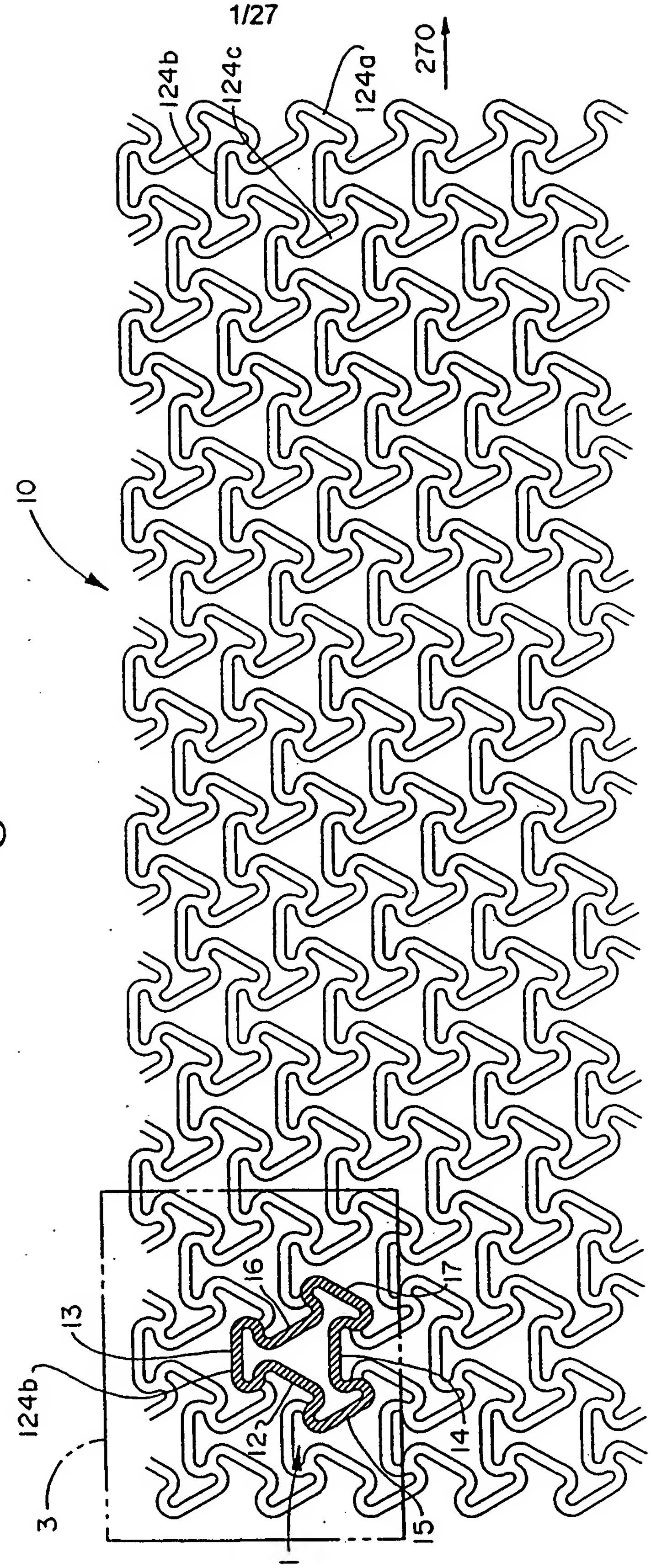


Fig. 1

Fig. 4

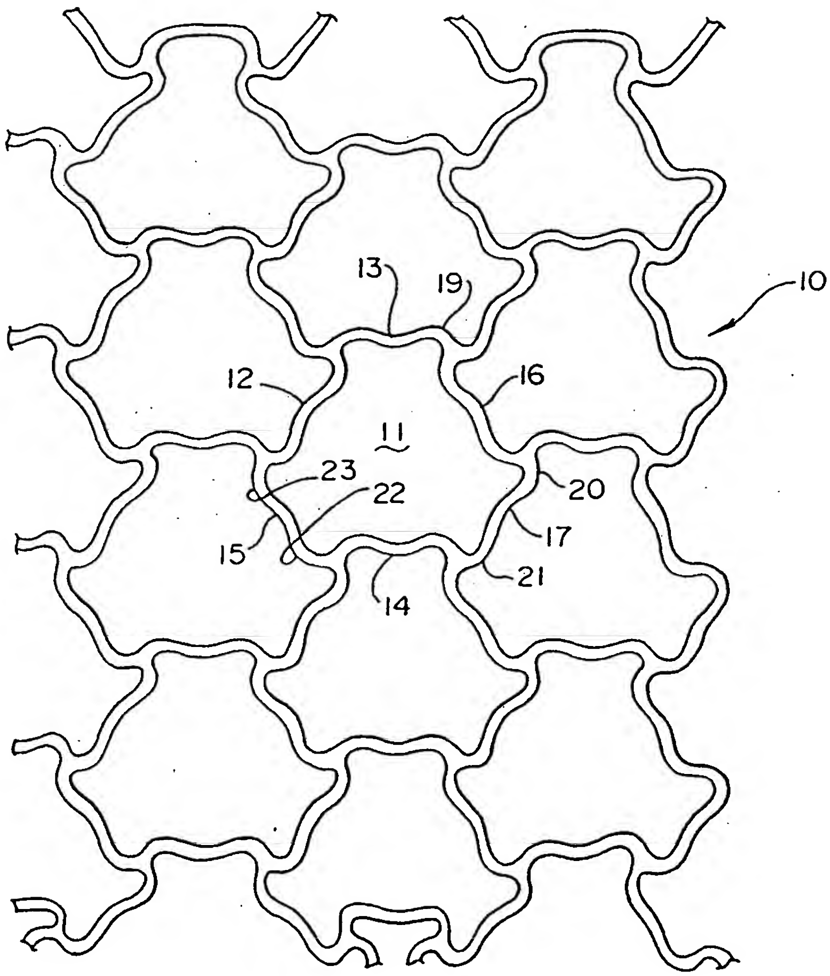
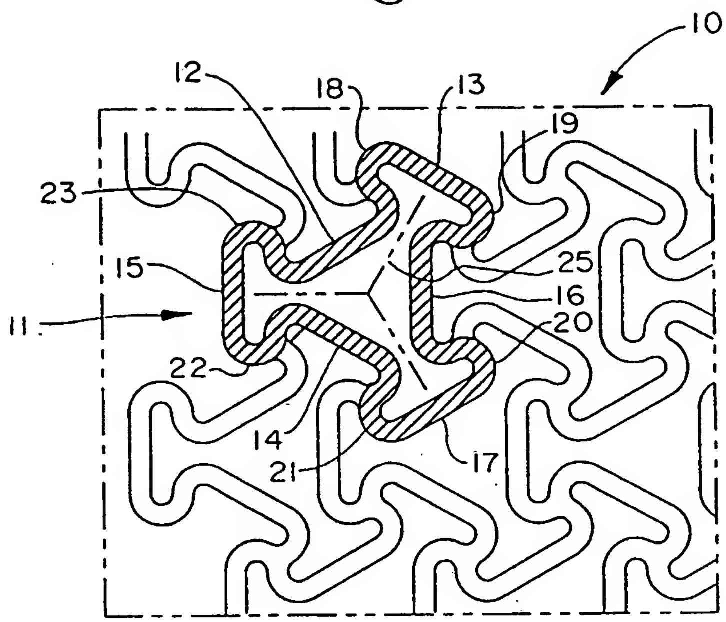


Fig. 6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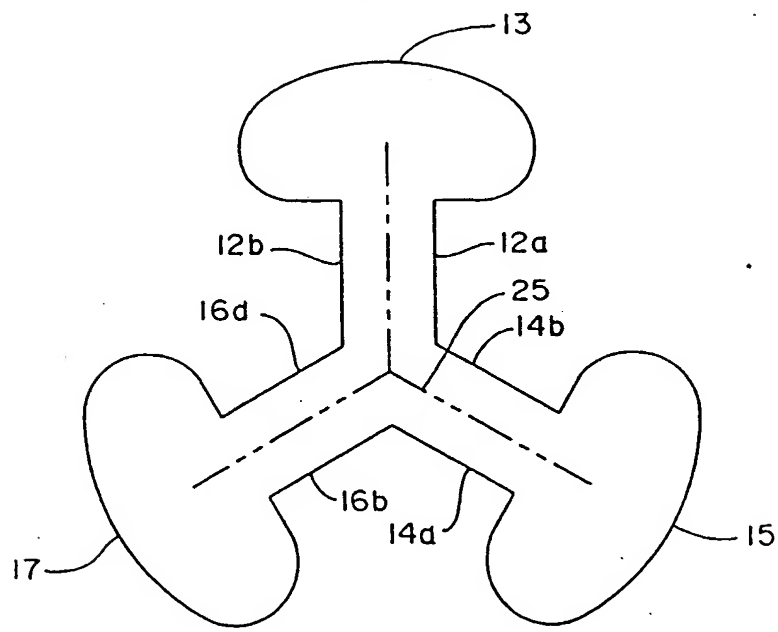
17

Fig. 8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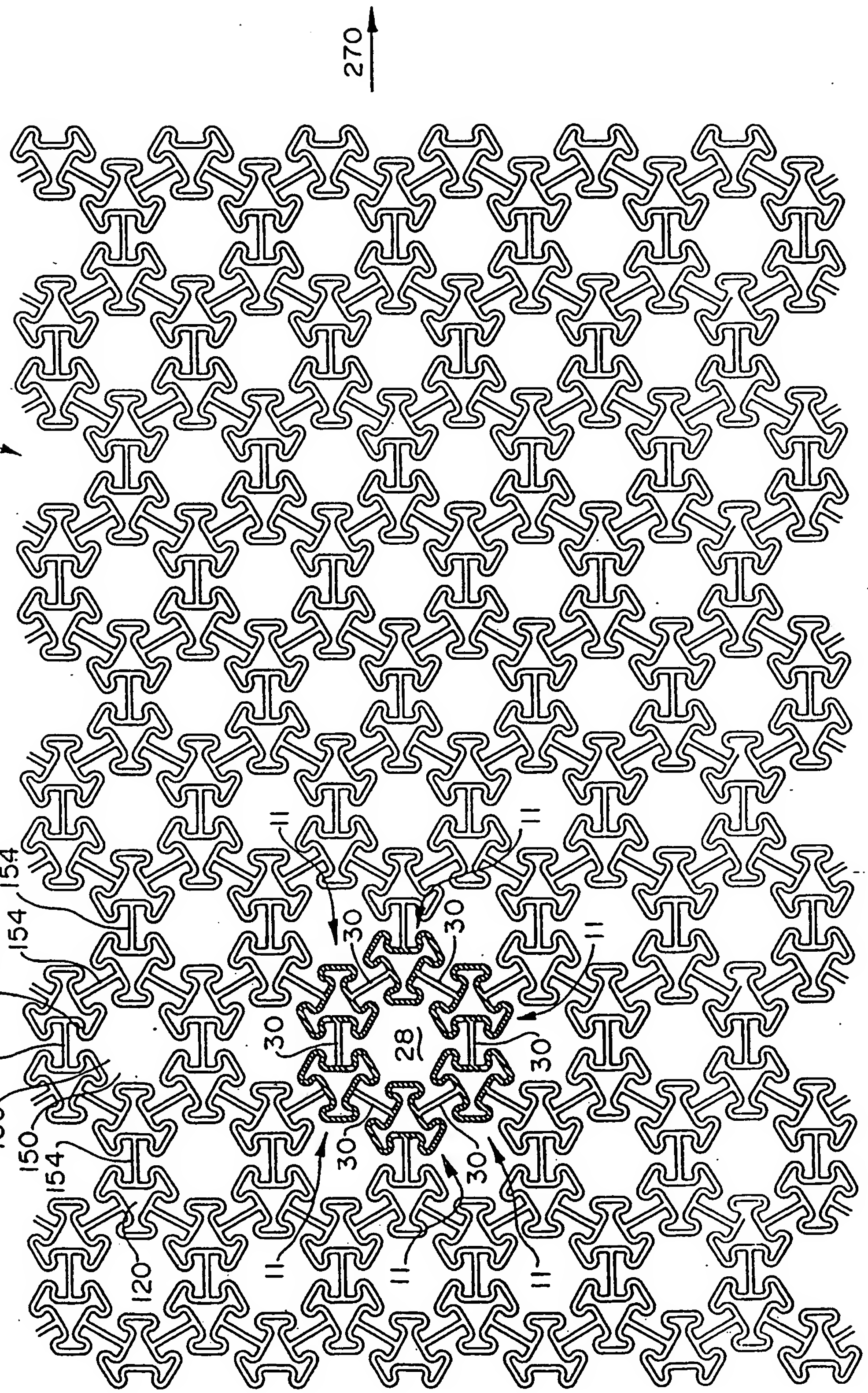
12b
12a
16d
25
14b
16b
14a
17
15


270
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11
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154
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162
154
166
150
154
120

Fig. 9

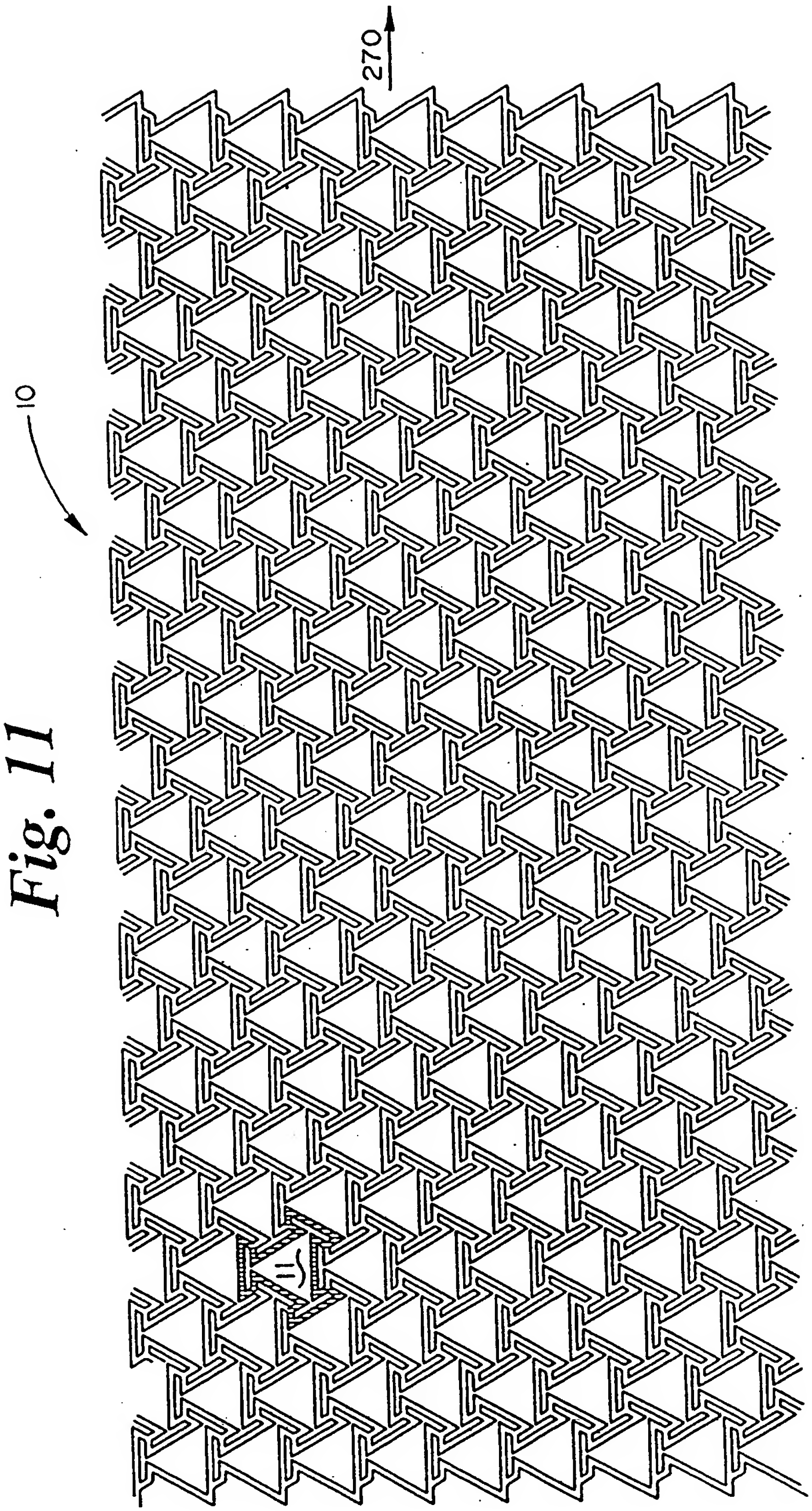
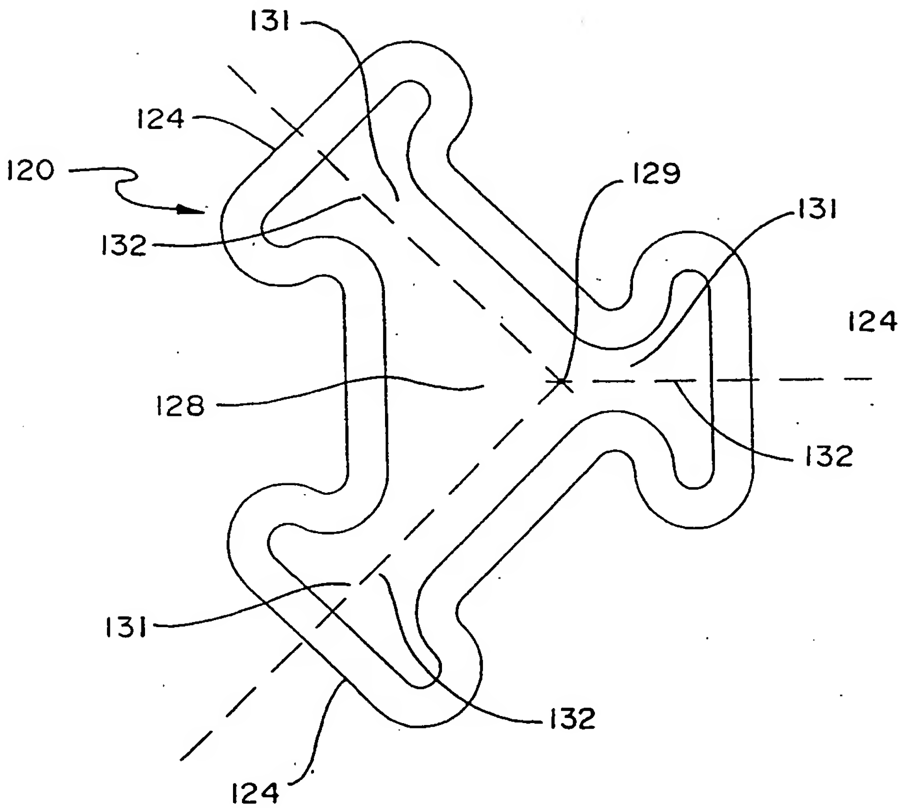


Fig. 11

Fig. 13



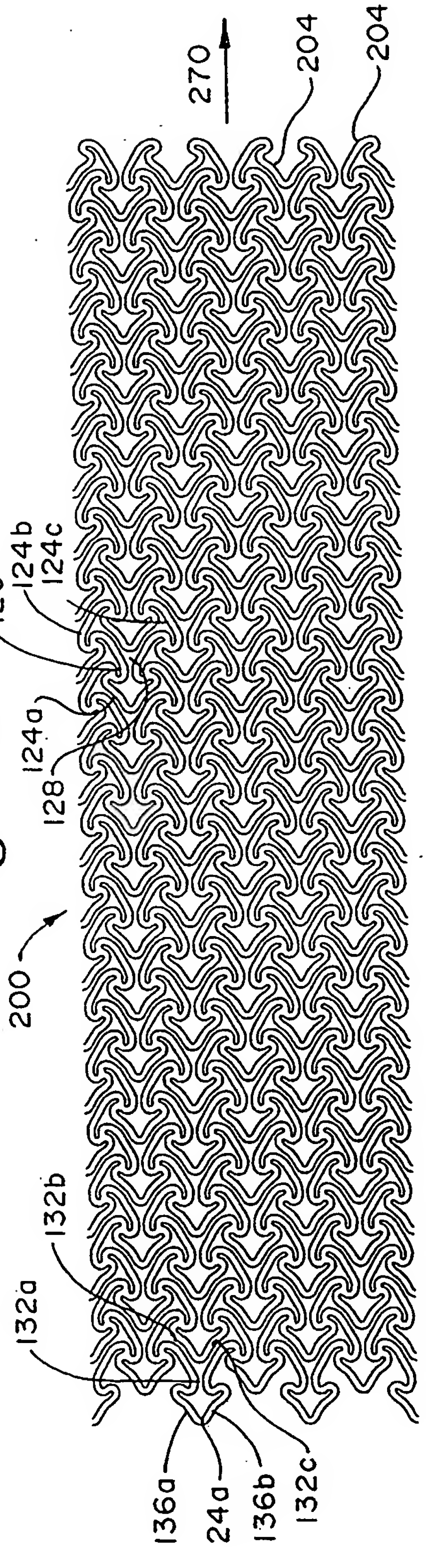


Fig. 15a

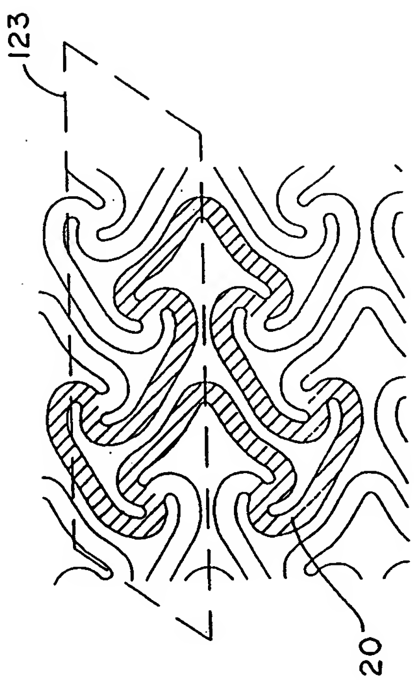


Fig. 15b

Fig. 16c

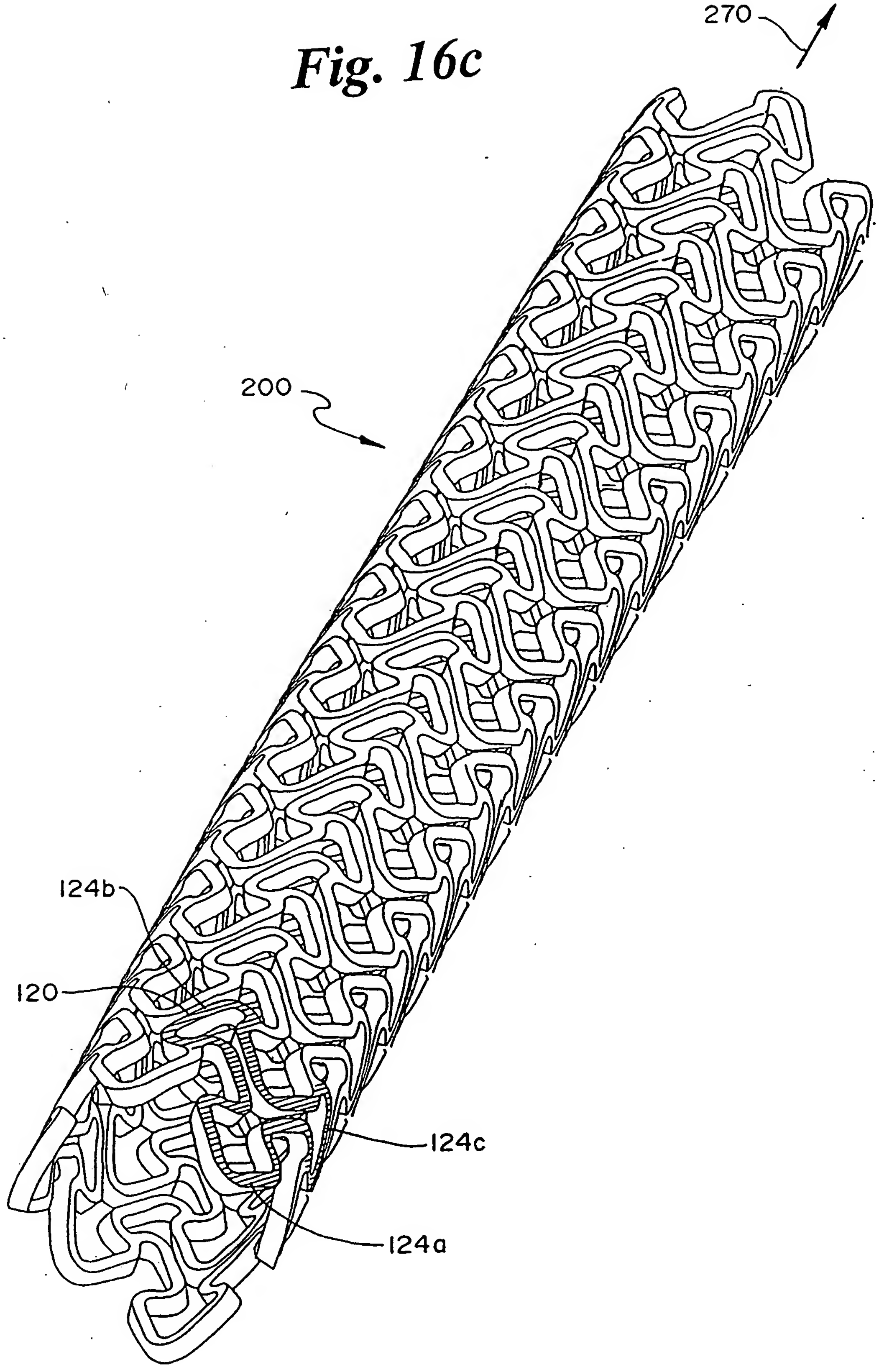
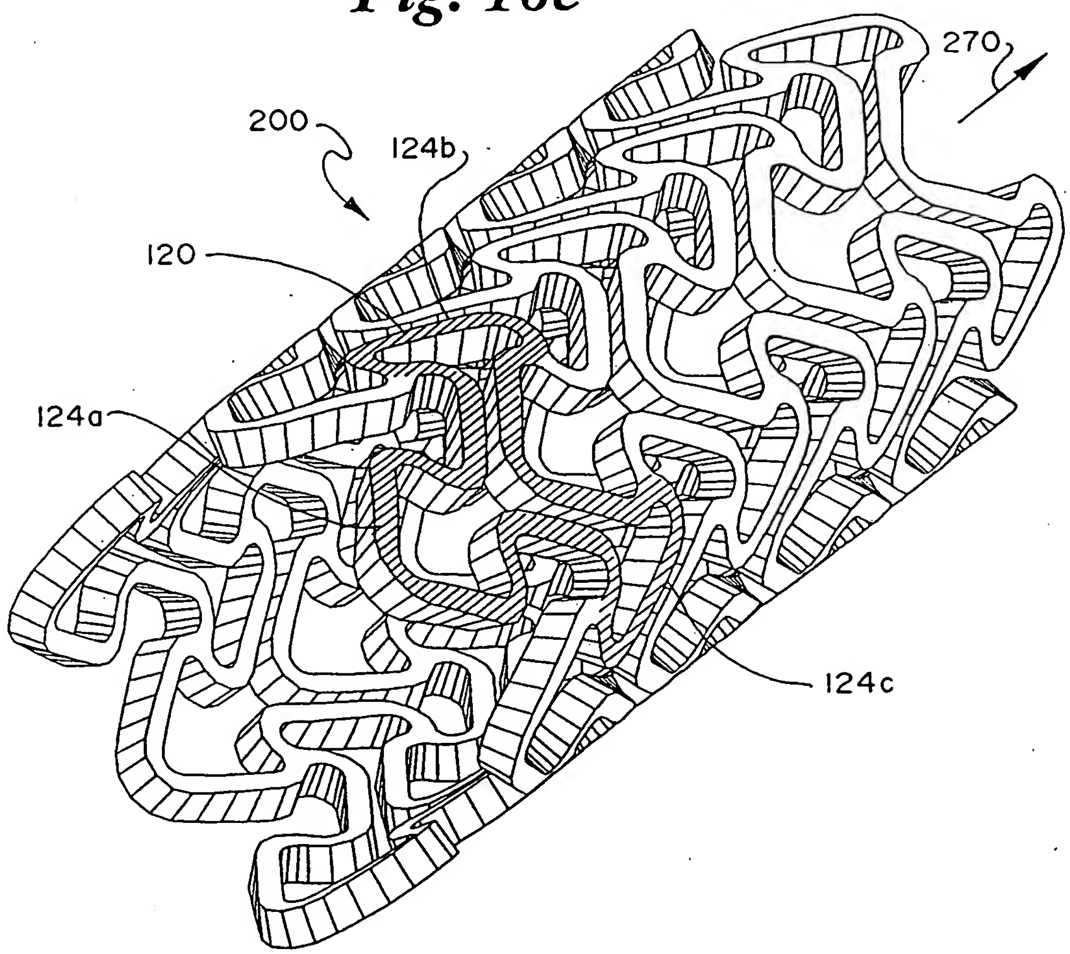


Fig. 16e



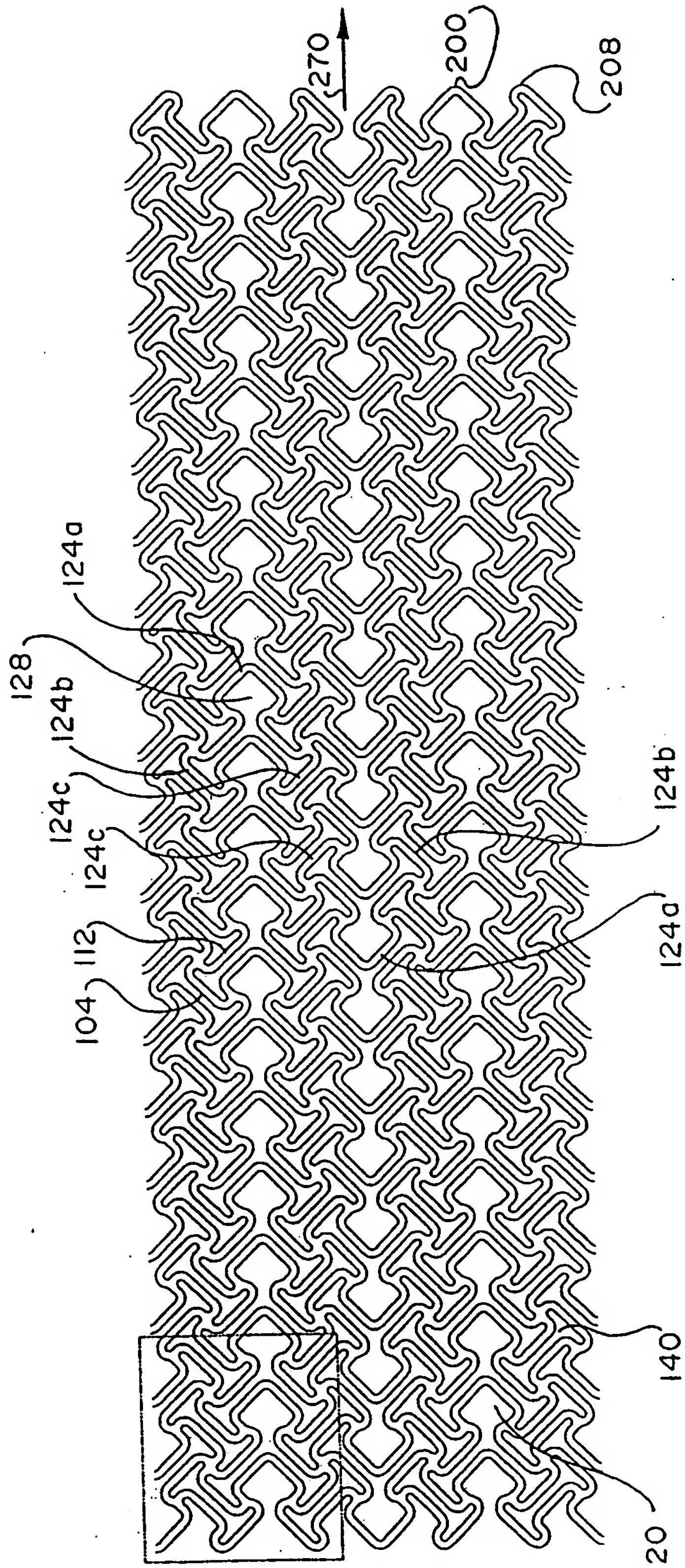
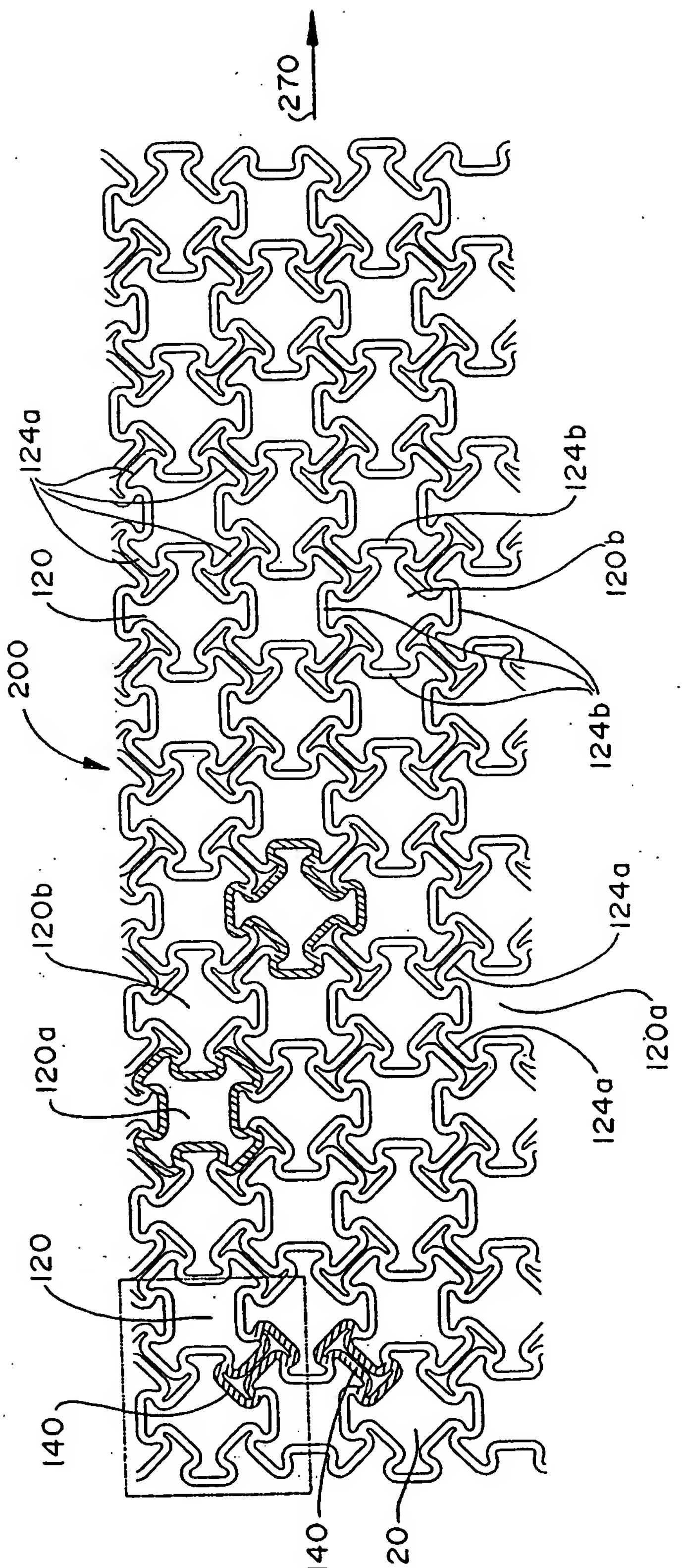


Fig. 18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120b
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124a
120a
120a
124a
120
140
140
120

Fig. 20a

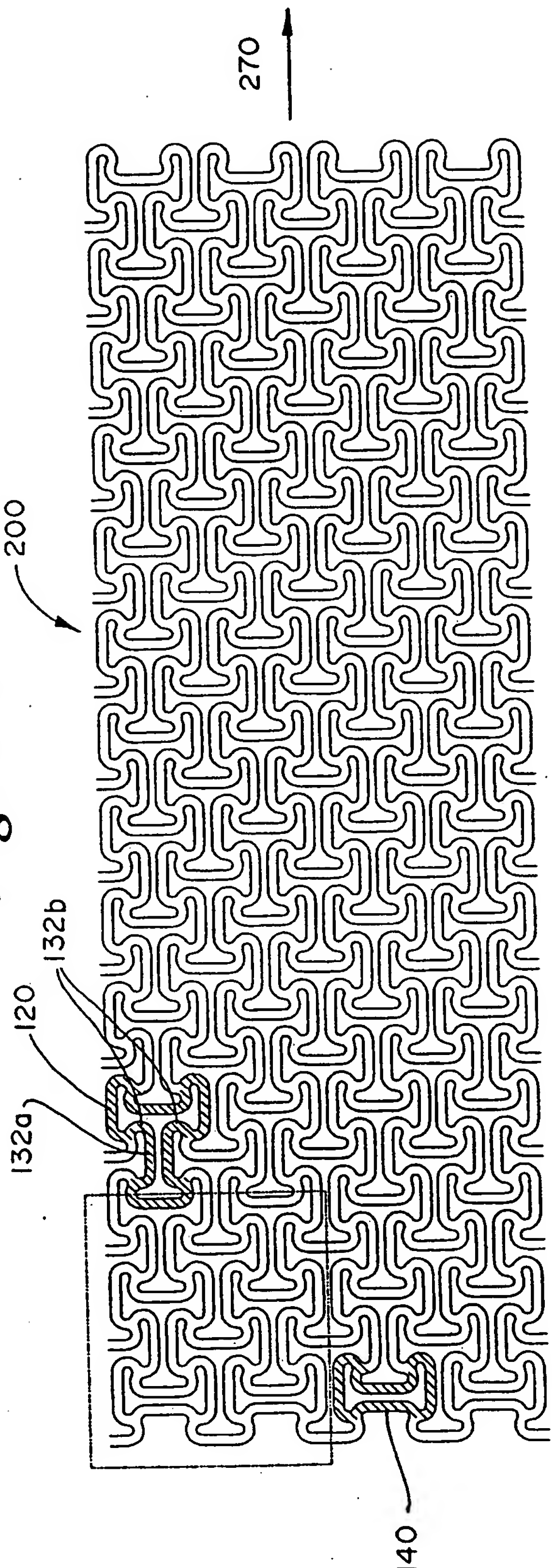
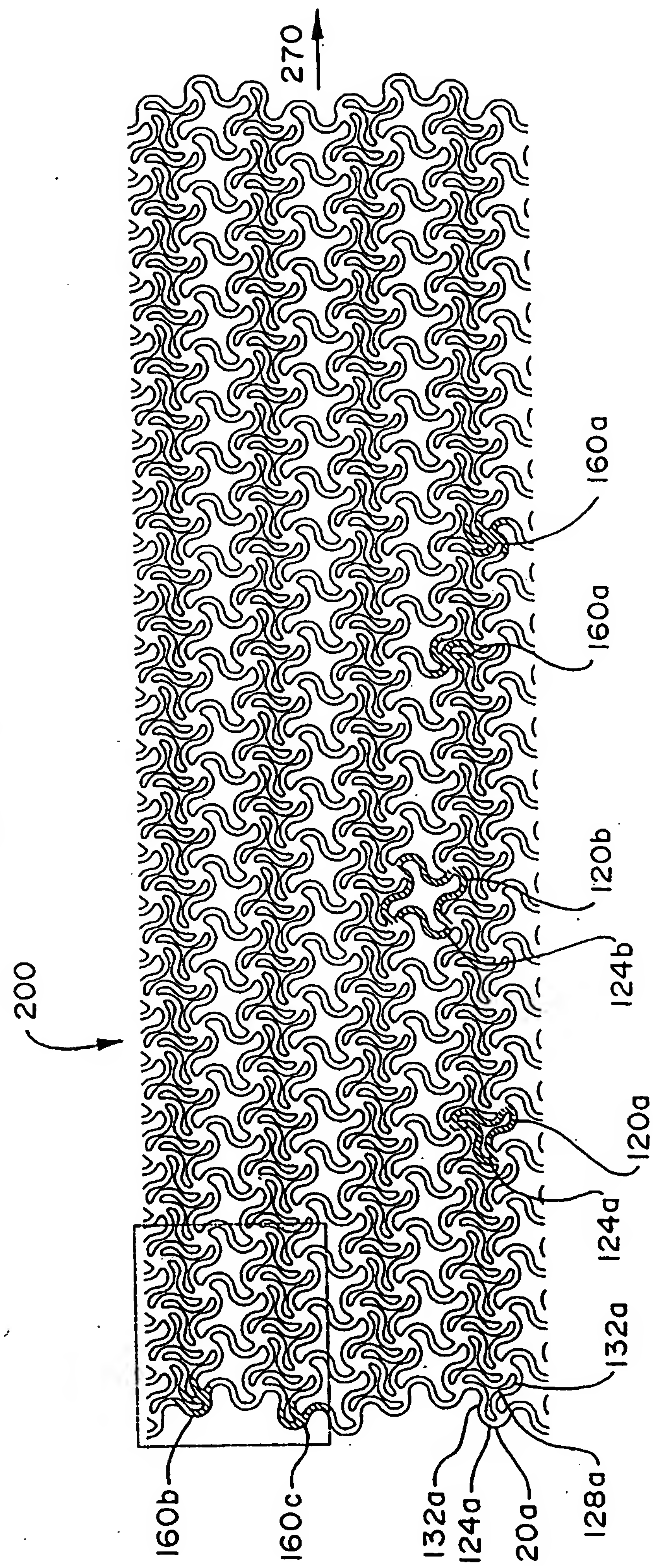


Fig. 21a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160c
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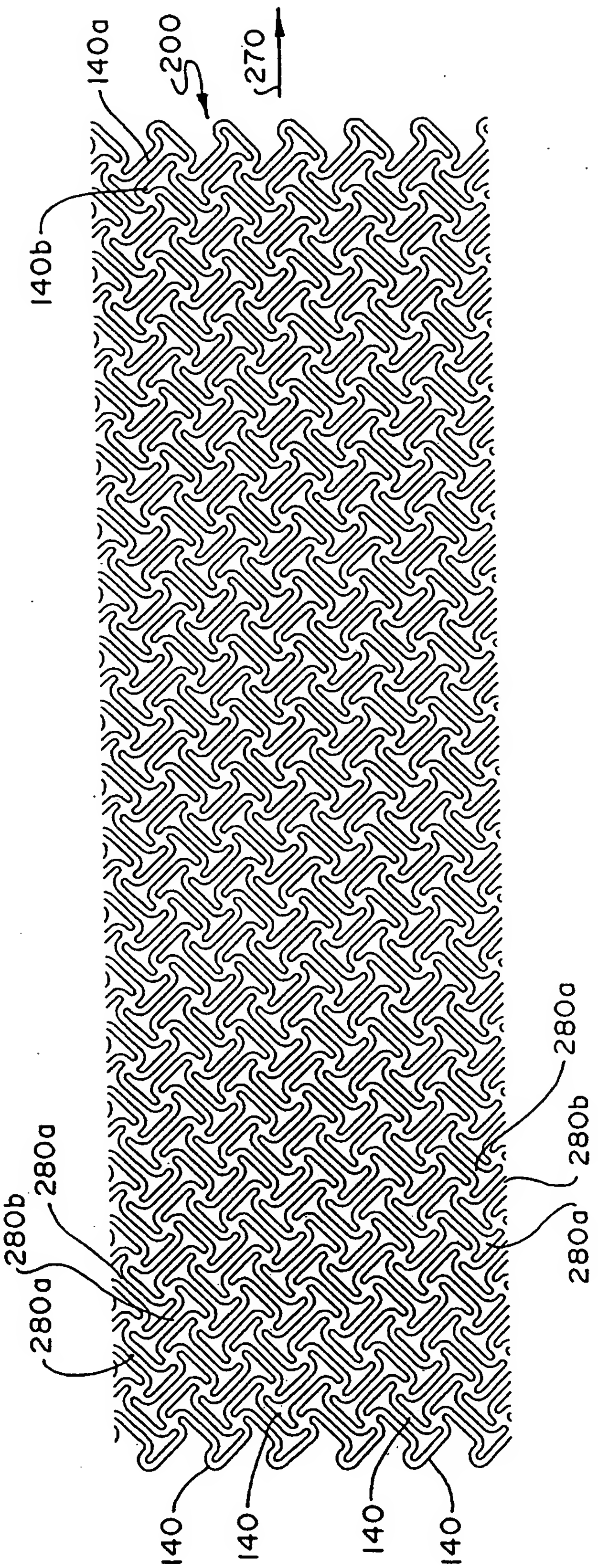
124a
120a
128a

Fig. 22a


140a
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280a
280b
280a
140
140
140
140

Fig. 23

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 99/04686

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